

AD 718383

Report No. 7071-4

MANUAL OF INSTRUCTIONS FOR THE ANALYTIC PROFILE SYSTEM

prepared for

Engineering Psychology Programs
Office of Naval Research
Arlington, Virginia 22217

under

Contract N00014-66-C0183
NR 196-076

Applied Psychological Services

Science Center
Wayne, Pa.

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

This document has been approved for public release and sale; its distribution is unlimited.

Reproduction in whole or in part is permitted for any purpose of the United States Government.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Applied Psychological Services		2a. REPORT SECURITY CLASSIFICATION Unclassified	
		2b. GROUP	
3. REPORT TITLE Manual of Instructions for the Analytic Profile System			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)			
5. AUTHOR(S) (First name, middle initial, last name) Corporate Author			
6. REPORT DATE December 1970		7a. TOTAL NO. OF PAGES 31 + ii	7b. NO. OF REFS 6
8a. CONTRACT OR GRANT NO. N00014-66-C0183		9a. ORIGINATOR'S REPORT NUMBER(S)	
b. PROJECT NO. NR 196-076		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) 7071-4	
c.			
d.			
10. DISTRIBUTION STATEMENT This document has been approved for public release and sale; its distribution is unlimited.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Engineering Psychology Programs Office of Naval Research	
13. ABSTRACT Information is presented regarding the application, scoring, and interpretation of the Analytic Profile System, a psychometric technique for performing a human factors evaluation of the visual displays in a man-machine system. A review of the research performed during the development of the technique is included.			

DDC
RECEIVED
FEB 25 1971
RECEIVED
B

Manual of Instructions for the Analytic Profile System

prepared for

**Engineering Psychology Programs
Office of Naval Research
Arlington, Virginia 22217**

by

**Applied Psychological Services, Inc.
Science Center
Wayne, Pennsylvania**

under

**Contract N00014-66-C0183
NR 196-076**

This document has been approved for public release and sale; its distribution is unlimited.

Reproduction in whole or in part is permitted for any purpose of the United States Government.

December 1970

TABLE OF CONTENTS

	<u>Page</u>
Introduction	1
Development of the APS	1
Reliability	4
Equivalence	5
Stability	6
Internal Consistency (Homogeneity)	7
Validity	8
Additional Psychometric Properties	9
Instructions for Application	22
Instructions for Scoring	23
Score Interpretation	25
Over-all Appraisal	28
GLOSSARY	29
REFERENCES	31

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Profiles of two displays on the seven dimensions.....	26

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	<u>D</u> -Values of Profile Similarity for Equivalence Among Four Evaluators on Three Panels	5
2	D-Values of Pre-Post Profile Similarity for Stability Estimation.....	6
3	Summary of Homogeneity of Each Dimension	7
4	Estimates of Concurrent Validity of Each Dimension and Total Score	8
5	Predictive Validity of Each Dimension and Total Score	9
6	Psychometric Properties of Statements Comprising Final Form	17

Introduction

The Analytic Profile System (APS) is a paper-and-pencil display evaluation instrument for use by human factors practitioners in evaluating a display relative to seven dimensions. It utilizes the forced-choice format, and the seven dimensions are based on factor analysis. The APS is not a human factors checklist, does not provide the same kind of information as the usual checklist of desired characteristics, and should not be used by individuals who are seeking the type of information checklists customarily provide. A checklist will usually be utilized to determine whether a display complies with particular specifications, standards, principles, and so forth. The APS will be used to determine the quality of a display from the point of view of the dimensions measured.

The APS is completely general and may be used for evaluating almost all types of visual displays. The instrument is intended to be used by individuals with some background in human factors, or display design, or related fields. Inasmuch as the use of the APS involves making judgments about the display(s) being evaluated, individuals without this background may lack the conceptual basis for performing a maximally valid evaluation, and may also encounter difficulty with the vocabulary of the instrument. As a partial aid to the user, a glossary is provided at the end of this Manual, but use of the APS by an individual who does not possess the appropriate background is nevertheless discouraged.

Development of the APS

The first step in the development of the APS was a set of multidimensional scaling analyses of the display/observer interface. These analyses are fully reported in Siegel and Fischl (1967) and in a journal article (in press) by the same authors. These analyses isolated the seven dimensions (factors) which are included in the APS. The dimensions are listed immediately below and are defined in the paragraphs which follow:

Dimension 1	Stimulus Numerosity (SN)
Dimension 2	Primary Coding (PC)
Dimension 3	Contextual Discrimination (CD)
Dimension 4	Structure Scanning (SS)
Dimension 5	Critical Relationships (CR)
Dimension 6	Cue Integration (CI)
Dimension 7	Cognitive Processing Activity (CA)

Stimulus Numerosity (SN)

Volume of material displayed. It pertains to the number of elements in the display observer's field of view. Some of these elements may be signal and some may be noise, but the more of either, the higher the Numerosity.

Primary Coding (PC)

General orienting format of the entire display. It pertains to the appropriateness of the medium or vehicle for conveying the display information. As such, it would be expected to differentiate in context such presentation methods as digital versus pointer and scale presentations of magnitudes, situational versus tabular presentation, and so forth.

Contextual Discrimination (CD)

Differentiation of relevant from irrelevant information. It pertains to signal-noise ratios present in the display and to the ease with which an observer might be expected to be able to differentiate between relevant and irrelevant information.

Structure Scanning (SS)

Organization of display signals into a meaningful structure. It pertains to the ease with which a display observer might be expected to be able to order or organize the material presented to him.

Critical Relationships (CR)

Relationships among displayed items and among the meanings represented by displayed items. It pertains to the ease with which a display observer might be expected to be able to order relationships in the displayed information.

Cue Integration (CI)

Integration of all cues to arrive at interpretation of what is portrayed. It pertains to the ease with which a display observer might be expected to be able to integrate all pertinent information so as to derive a consistent understanding of the situation presented.

Cognitive Processing Activity (CA)

Information processing to derive a course of action. It pertains to decision making processes and to the extent that a given display supports, facilitates, or inhibits decision making.

Following the determination of the seven dimensional display/observer interface space, prose statements were prepared which pertained to each of the dimensions. A total of 227 statements was prepared in seven pools, one pool per dimension. To accommodate the forced choice methodology, indexes of the favorableness of each statement in the pools were next obtained. Twenty-nine members of the Delaware Valley and the Potomac Chapters of the Human Factors Society rated the statements along a 100-point scale of favorableness. The mean scale value over all judges for each statement was taken as the statement's favorableness index.

Following the favorableness index determination, sufficient information was available to permit selection of statements from the pools and assembly of the instrument. The goal for the ultimate instrument was the tetrad form, each tetrad consisting of two favorable and two unfavorable statements. To permit the seven dimensions to be represented in equal frequency, 35 tetrads were required. This necessitated the selection of 20 statements per dimension. Each of these 20 statements required a "mate" of matching favorableness but which tapped a different dimension. It was considered desirable for half the matches to involve favorable statements, half unfavorable.

An initial cull of statements was made, identifying those from each dimension which had the smallest favorableness standard deviations. From among these, 70 pairs of statements were assembled on the basis of: (a) equivalent favorableness, (b) equal representation of favorable and unfavorable statements from each dimension, and (c) content compatibility. The favorableness indexes of the paired statements were, with few exceptions, within one standard error of their differences. The exceptions were only slightly more disparate, and each dimension contributes exactly ten favorable statements and ten unfavorable statements. The pairs were then assembled into tetrads. Each tetrad consisted of a favorable pair and an unfavorable pair of statements, and each statement within a tetrad tapped a different display dimension. The favorableness index of the favorable pair was in each case just about as much above 50 (the scale midpoint) as the unfavorable pair's index was below 50. In no tetrad are the favorable and unfavorable pairs any closer together in favorableness than four times the standard error of their difference; and over all tetrads, statements are arranged so that each dimension appears in each of the four positions with approximately equal frequency.

Reliability

Reliability determinations for the APS were first reported in Siegel, Fischl, and Macpherson (1969). Within the general area of psychometric reliability, equivalence, stability, and internal consistency (homogeneity) were investigated. The first of these properties was examined from the point of view of the correspondence of results from the independent use of the instrument by four human factors specialists who evaluated the same displays. To investigate the second property, three of these four human factors specialists reevaluated the displays after intervals of two, four, and five months respectively, and the correspondence of each judge's pre and post evaluation of these displays was examined. These equivalence and the stability investigations were performed utilizing the same three visual displays. They were the instrument panels of the F9F aircraft and the 1968 Dodge Dart automobile, and the target bearing time recorder of a submarine sonar system under development. Homogeneity was investigated as the correlation of each statement's score with the total score for its dimension, obtained from application of the instrument to two different designs of the following equipments:

1. Public Address Set AN/UIH-3, a portable unit for amplification of voice communication to audiences in open fields or enclosed auditoriums
2. Radar Set AN/FPS-56, an air search radar console
3. Air Defense Target Assignment Equipment
4. Radio Set AN/GRC-50, a mobile radio set for two-way communications within a line-of-sight range
5. Radio Set AN/GRC-66, a radio relay set, mobile, and for use in rear and intermediate field situations
6. Radar Set AN/MPQ-29, a mobile tracking and plotting air defense radar
7. Radar Set AN/TPS-33, a portable transmitter-receiver set used to search for, detect, and track moving targets on the ground
8. Radar Set AN/MPQ-4A, a mobile intercept radar for location of high angle trajectory weapons

Equivalence

Profiles of each of the three displays were obtained over the seven dimensions of the APS. To assess the extent of similarity in the profiles of the same display rendered by the different evaluators, D-values (Osgood & Suci, 1952) were calculated. Table 1 presents the resultant D-values.

Table 1
D-Values of Profile Similarity for
Equivalence Among Four Evaluators on Three Panels

	Evaluator	A	B	C	D
Auto Panel	A		6.32	10.68	11.22
	B			14.14	12.33
	C				14.35
Sonar Display	A		14.56	10.39	10.39
	B			13.78	15.36
	C				13.86
Aircraft Panel	A		31.24	23.15	14.70
	B			21.26	38.96
	C				25.11

D-values are inverse indicators of profile similarity, with zero indicating perfect agreement. Maximum disagreement is a function of the score range and the number of profile points involved. In the present case, the maximum possible disagreement or dissimilarity in profiles would yield a D-value of 72.11.

As a preliminary indication of equivalence, Table 1 shows equivalent results in two applications and marginal equivalence in a third. If one accepts the median D of Table 1 as the best single estimate of equivalence, then between 13 and 14 becomes the overall equivalence estimate.

A more recent estimate of equivalence was obtained in the context of an additional validation study (Fischl & Siegel, 1970). Two human factors specialists independently applied the APS to eight visual displays. The product moment correlation between the total APS scores yielded by the evaluators was .98.

The between rater product moment correlation for each subscale was:

Scale	r
Stimulus Numerosity	.91
Primary Coding	.97
Contextual Discrimination	.95
Structure Scanning	.91
Critical Relationships	.97
Cue Integration	.94
Cognitive Processing Activity	.95

Stability

Stability was estimated by having the displays reevaluated by three of the four human factors specialists who had performed the evaluations for equivalence estimation. One of these reevaluations took place after an interval of two months, one took place after four months, and one took place after an intervening period of five months.

D-values were calculated to obtain quantitative expressions of the similarity of the pre-post profiles. These are presented in Table 2. The median D is between 11 and 12, and this value is interpreted as indicating satisfactory overall stability.

Table 2

D-Values of Pre-Post Profile Similarity for Stability Estimation

	<u>Auto Panel</u>	<u>Sonar Display</u>	<u>Aircraft Panel</u>
Evaluator A	10.77	12.73	31.24
Evaluator B	10.39	21.95	12.81
Evaluator C	8.37	11.22	10.20

Internal Consistency (Homogeneity)

For investigating subscale homogeneity, a human factors specialist (Evaluator A) applied the instrument to each of 16 displays. Statement scores (+1, 0, and -1) were dichotomized on a plus or minus basis, with the zero scores being assigned equally to both categories, and the total score for each dimension was dichotomized at the median of the distribution of these scores over the 16 equipments. To investigate the correlation of the set of statements keyed to each dimension and that dimension score, phi coefficients were obtained through the procedure described by Jurgensen(1947).

The range of these values was from minus .11 to plus .93. Most of the correlation coefficients were of intermediate magnitude. Twenty-six of the 140 statements yielded values lower than 0.17. These were replaced with statements (of about the same favorableness) from the original pool, the 16 displays were again evaluated, and the correlations of statement scores with dimension scores were recomputed. The final form of the instrument was assembled on the basis of the resulting homogeneity coefficients. Table 3 summarizes the homogeneity coefficients for the set of finally selected items.

Table 3

Summary of Homogeneity of Each Dimension

<u>Dimension</u>	<u>Mean r*</u>
Stimulus Numerosity (SN)	.62
Primary Coding (PC)	.56
Contextual Discrimination (CD)	.44
Structure Scanning (SS)	.42
Critical Relationships (CR)	.49
Cue Integration (CI)	.44
Cognitive Processing Activity (CA)	.50

* utilizing z' transformation

Validity

The concurrent validity of the APS was investigated by Siegel, Fischl, and Macpherson (1969). The same 16 displays were utilized as for the homogeneity determinations. A score on the seven APS dimensions, as well as a total score, was involved for each display. As stated previously, the 16 displays involved two versions of each of eight different equipments, and the versions had been judged by experienced human factors specialists to be the best and worst of several alternate versions of each equipment. These judgments comprised the criterion against which the concurrent validity of the APS was evaluated.

For each of the seven dimensions, as well as for total score, a fourfold classification of "best" and "worst" version of the equipment and "higher" or "lower" APS score was established. To determine the correspondence of higher or lower score with best or worst version of equipment, phi coefficients were obtained. Table 4 presents the resulting phi coefficients:

Table 4

Estimates of Concurrent Validity of Each Dimension and Total Score

<u>Dimension</u>	<u>Validity Coefficient (phi)</u>
Stimulus Numerosity (SN)	.50
Primary Coding (PC)	.75
Contextual Discrimination (CD)	.50
Structure Scanning (SS)	.00
Critical Relationships (CR)	.25
Cue Integration (CI)	.50
Cognitive Processing Activity (CA)	.75
Total Score	.75

The Structure Scanning and Critical Relationships dimensions did not yield acceptable validities in this initial validation. They were apparently not relevant to the context of the displays employed.

More recently, the predictive validity of the APS was investigated (Fischl & Siegel, 1970). Two human factors specialists applied the APS to 24 stimulus variations of two basic display types. Then, 10 college students were trained to proficiency in the use of these displays and were administered a performance test requiring their use in the solving of operational types of problems. To answer the question of how well the APS scores predicted performance, point biserial correlation coefficients were obtained between continuous APS scores on each dimension, and performance scores dichotomized by the two display types. These coefficients of predictive validity are shown in Table 5.

Table 5

Predictive Validity of Each Dimension and Total Score

<u>Dimension</u>	<u>Validity Coefficient (r_{pb})</u>
Stimulus Numerosity (SN)	.79
Primary Coding (PC)	.88
Contextual Discrimination (CD)	.81
Structure Scanning (SS)	.88
Critical Relationships (CR)	.85
Cue Integration (CI)	.84
Cognitive Processing Activity (CA)	.52
Total Score	.87

Additional Psychometric Properties

The statements comprising the final form of the instrument are presented in Table 6. These are shown in the context of the tetrads to which they pertain. The table also indicates the dimension to which each statement is keyed, the correlation of the statement with the dimension, the associated favorableness index, and the standard error of the favorableness index.

In the Fischl and Siegel (1970) study, APS total scores of a group of displays were compared with scores these displays received on a typical human engineering checklist. The product moment correlation coefficient was .71. This value was interpreted as indicating a general similarity between the results obtained from application of the two instruments, but that additional variance (approximately 50 per cent) is unique to the APS.

Table 6

10.

Psychometric Properties of Statements Comprising Final Form

	Dimension	r	Favor- ableness	Standard Error
1.				
a. Does not seem to be organized as well as it might with respect to the operational logic involved.	SS	.88	35	2.2
b. The way the information is presented seems quite conducive to user integration of this information.	CI	.57	70	3.0
c. The implications of certain of the displayed data for other displayed data are not easy to comprehend.	CR	.09	31	2.9
d. Although the information content may be high, the number of separate sensory inputs to the user seems modest.	SN	.72	65	4.6
2.				
a. Although the amount of material presented is not excessive, the format of the display makes it seem so.	CD	.22	28	2.4
b. Various aspects of the display seem to complement each other in permitting the user to bring together a consistent interpretation.	PC	.57	76	3.0
c. The meaning of at least certain of the information items in this display is difficult to comprehend.	SS	.41	26	4.1
d. The visual experience is definitely <u>not</u> one of seeing a congested display.	SN	.50	70	4.0
3.				
a. The format of this display is not conducive to presenting information in the form in which it will be used.	PC	.91	15	2.6
b. A highly understandable display because of its organization.	SS	.11	88	2.3
c. In viewing this display, the necessary perceptions are virtually self-organizing.	CD	.69	89	2.4
d. Cues in this display are of such disparate orders of magnitude and in so many different types of scales that integration is quite difficult.	CI	.30	16	3.4

	Dimension	r	Favor- ableness	Standard Error
4.				
a. Materials of the same type are generally similar appearing and differentiable from materials of different types.	CD	.19	77	2.9
b. Major relationships, which are important for interpretation of the situations displayed, do not seem readily perceptible.	CR	.39	22	3.6
c. Because of the format and the coding scheme, interpretation is fairly straightforward.	SS	.75	78	3.1
d. There may be a problem of maintaining attention because of the large number of stimuli appearing in the visual field.	SN	.50	33	4.5
5.				
a. The method of organization of the displayed material is not particularly apparent.	PC	.61	33	3.3
b. From the point of view of number of items striking the user, this display seems to present about as few as possible.	SN	.49	63	5.4
c. The stimuli presented do not seem to fall into as natural groupings as they might.	CD	.09	35	2.5
d. Once the user masters the few ground rules of this display's organization, integrating the information will not be difficult.	CI	.47	68	3.7
6.				
a. Information for decision-making is presented in a form that can be employed directly.	CA	.31	87	3.2
b. When one tries to integrate all of the information presented, he is just overwhelmed.	CI	.60	12	2.8
c. Relationships which are critical for the operational use of the display are readily apparent to the user.	CR	.64	88	2.0
d. This could be a display of anything--one hardly has content cues to assist in interpretation.	SS	.09	13	3.1

	Dimension	r	Favor- ableness	Standard Error
7.				
a. Considering the content-material involved, the format of this display is quite appropriate.	SS	.11	74	3.6
b. A relatively small number of signal elements is presented and there is relatively little noise in the display.	SN	.49	70	2.9
c. The user who needs trend-type information will have difficulty getting it.	PC	.09	25	3.6
d. Considerable intermediate information processing is required of the user.	CA	.77	24	3.6
8.				
a. This method of representation falls short with respect to providing a needed over-all perspective.	PC	.61	33	3.7
b. It is a little difficult to see or infer relationships among the materials presented.	CR	.60	38	2.6
c. Cues from different sources, which the user must integrate are either grouped or combined for him.	CI	.85	75	3.7
d. There seems to be a nice correspondence between the operational meaning of the displayed material and the method chosen to display it.	SS	.00	78	3.3
9.				
a. The action of some objects or situations on other objects or situations represented in this display is not as easy to comprehend as it might be.	CR	.91	35	1.9
b. Considering integrations which the user might have to perform, the number of error-likely places is quite small.	CI	.17	71	3.7
c. The things presented seem to fall into natural groupings.	CD	.28	69	2.7
d. To read this display the user must consider quite a few items.	SN	.78	34	2.8

	Dimension	r	Favor- ableness	Standard Error
10.				
a. There is just too much being presented.	SN	.64	20	3.0
b. The format of this display is not conducive to presenting information in the same degree of precision as is required by the user.	PC	.82	20	3.0
c. The display seems organized in a way that makes relationships easy to see.	CR	.50	79	2.4
d. The organization of the display facilitates interpretation of the displayed material.	SS	.77	80	2.1
11.				
a. Considering the content-material involved, I am a little surprised at the over-all method of representation.	SS	.16	40	3.4
b. Seems to be a little "busy".	SN	.93	40	2.1
c. The difficulty of the decision making process seems to be minimized because of the manner of display.	CA	.72	74	2.6
d. Because of the coding methods utilized, there is little difficulty determining which categories of materials belong together.	CD	.28	74	3.4
12.				
a. Most calculations and other intermediate information processing functions are performed for the user, and results presented to him.	CA	.82	79	3.8
b. The organization and arrangement of the display is such that integration of its various information items is not difficult.	CI	.31	71	3.9
c. The over-all method of representation seems deficient as a vehicle for conveying the display's information content.	PC	.16	27	4.5
d. Decision-making could be facilitated by an alternative organization schema.	SS	.39	34	4.1

	Dimension	r	Favor- ableness	Standard Error
13.				
a. Differentiating between some of the things presented could be difficult.	CD	.52	32	3.1
b. Contains a relatively small number of items.	SN	.58	60	3.7
c. The influence that most displayed items have on other displayed items is reasonably apparent.	CR	.77	68	2.4
d. Decisions that the user makes would seem to involve fairly heavy intellectual loads.	CA	.50	33	4.6
14.				
a. Reading this display involves examining only a few elements.	SN	.64	76	3.6
b. It is not easy to cross-check or cross-compare for relationships in the displayed information.	CR	.39	22	4.1
c. The over-all format of this display seems to be a natural and proper one.	PC	.50	74	3.8
d. The number of conversions or translations required impedes integration of at least some of the information.	CI	.56	26	3.1
15.				
a. The presentation does not seem to foster comprehension of relationships in the display.	CR	.30	19	2.6
b. Interacting with this display is a difficult perceptual task.	CD	.61	21	3.7
c. The general presentation method of this display seems well keyed to the operational meaning of the material.	SS	.11	81	3.0
d. This method of presentation is conducive to highlighting key aspects of the situations represented.	PC	.33	80	3.0

	Dimension	r	Favor- ableness	Standard Error
16.				
a. This presentation is not readily conducive to extraction of the meaning of the displayed information.	SS	.09	21	3.6
b. Cross-checking, or cross-comparing, for relationships in the displayed information, can be carried out rather easily.	CR	.00	77	3.1
c. Decision-making on the basis of this display seems to require the user to do some difficult mental processing.	CA	.60	22	3.0
d. The display seems to facilitate bringing organization to the perceptual field.	CD	.69	76	3.0
17.				
a. Understanding interactions among objects or circumstances is helped because of the way they are represented in the display.	CR	.22	76	2.9
b. The display gives the appearance of being very filled with material.	SN	.50	34	3.0
c. Decision-making on the basis of this display seems to involve a considerable amount of information processing by the user.	CA	.16	34	2.7
d. The information codes are realistic, thus helping the user to infer the intended meanings.	SS	.20	76	2.8
18.				
a. The user who needs to interpret some of the displayed information in the perspective of other display information will probably be able to do so without much difficulty.	CR	.83	64	3.4
b. Considerable additional mental activity seems to be necessary for decision-making on the basis of this display.	CA	.50	27	2.5
c. Even though there is obvious noise present, the display still does not appear cluttered.	SN	.38	61	3.4
d. The over-all method of presenting information is not too well keyed to operations.	PC	.49	26	3.1

	Dimension	r	Favor- ableness	Standard Error
19.				
a. Seems to be a fairly "clean" display.	SN	.47	62	3.2
b. If any integration of display information should be necessary, the user will have a heavy burden.	CI	.00	23	4.3
c. Considerable material is presented but the format is conducive to ordering this material.	CD	.19	69	3.1
d. The organization of this display may actually impede tactical decision-making.	SS	.30	18	3.3
20.				
a. Even though a sizable amount of information may be presented, integrating this information is not difficult for the user.	CI	.09	74	3.2
b. The over-all method of information representation is such that little additional calculation or conversion of information is necessary.	PC	.57	74	3.2
c. There seems to be considerable reliance on user memory.	CA	.69	23	3.4
d. The user who needs to interpret certain of the displayed information in the perspective of other displayed information will find it difficult to relate the two.	CR	.19	24	3.4
21.				
a. The information seems well presented for the decisions which have to be made.	CS	.56	81	2.4
b. The typical user could be expected to recognize his decision alternatives quite readily in this display.	CA	.20	82	2.6
c. Assembly of individual items into meaningful classes of information would seem difficult.	CI	.30	25	2.6
d. At first glance it is hard to differentiate prime material from ancillary material.	CD	.47	29	3.3

	Dimension	r	Favor- ableness	Standard Error
22.				
a. The presentation modes of the display seem to provide a good number of content cues, which are helpful.	SS	.41	73	2.6
b. The over-all method of information representation forces the user to do some additional calculations or conversions.	PC	.60	27	3.4
c. All things considered, the number of items appearing in the visual field is quite modest.	SN	.69	67	3.9
d. I can foresee user difficulty in integrating this information.	CI	.50	28	3.0
23.				
a. The over-all organization and appearance of the display, although appropriate for some uses, is not maximally appropriate for the way this information will be used.	PC	.30	34	3.0
b. Integrating the displayed information to derive a clear understanding of what is going on seems to take longer than it should.	CI	.69	36	2.5
c. Solution of tactical problems can take place with a reasonably small number of mental steps or acts.	CA	.60	65	5.0
d. At first glance seems to be relatively uncluttered.	SN	.09	58	2.6
24.				
a. When you look at this display there is an awful lot in your visual field.	SN	.91	36	4.0
b. The over-all method of representation seems to be suitable for conveying the display's information content.	PC	.50	72	3.2
c. Related matter is grouped meaningfully.	CR	.39	71	3.8
d. Certain materials which are quite similar in nature are presented in rather extremely different ways.	CD	.41	36	4.0

	Dimension	r	Favor- atleness	Standard Error
25.				
a. The format of this display lends itself to presenting information in the same form as it will be used.	PC	.50	82	3.7
b. The organization of the display is at variance with the logical and natural organization of the information.	SS	.38	20	4.0
c. Decision trade-offs are difficult to make because of the amount and/or form of the information presented.	CA	.36	21	2.3
d. Important relationships among the displayed materials are readily discernible.	CR	.64	81	2.1
26.				
a. It may not be easy to recognize decision alternatives in the display.	CA	.69	32	4.1
b. The subject-matter logic is quite apparent from the way the information is presented.	SS	.09	82	3.0
c. At least some materials which are qualitatively different seem to be rather similar in appearance.	CD	.11	32	3.0
d. The format of this display lends itself to presenting information in the exact degree of precision as the information will be used.	PC	.31	85	2.5
27.				
a. I see little user difficulty in integrating this information.	CI	.38	78	3.2
b. The number of visual inputs to the user seems considerable.	SN	.49	39	2.8
c. Interpretation of this display is not as easy as it might be if a different format or different coding scheme were presented.	SS	.93	36	4.5
d. The information presentation seems to be keyed to operational decisions.	CA	.22	80	3.6

	Dimension	r	Favor- ableness	Standard Error
28.				
a. The choice of over-all format for this display seems to have been a good one.	PC	.41	74	2.7
b. I would expect even a relative novice to have little difficulty separating the similar-meaning and the dissimilar-meaning material.	CD	.77	78	4.0
c. At first glance seems to be somewhat cluttered.	SN	.19	36	4.1
d. There seems to be a considerable amount of mental processing required of the display user.	CA	.68	30	2.6
29.				
a. The basic organization of the display does not lend itself very readily to integration.	CI	.52	30	2.6
b. The information which the user must process mentally does not seem to be of a particularly difficult nature.	CA	.35	70	4.4
c. Although there is relatively little noise in this display, the large number of signals yields the effect of a cluttered display.	SN	.93	31	3.6
d. Information is presented in a way which allows the user to induce relationships fairly easily.	CR	.28	72	2.7
30.				
a. Scanning the entire display involves scanning a great many separate items.	SN	.50	34	3.2
b. Information is arranged so that decisions may be made with only moderate degrees of additional mental activity.	CA	.20	71	4.5
c. The time required to integrate the various information items seems minimal.	CI	.57	73	3.8
d. There could be some difficulty differentiating signal from noise in this display.	CD	.28	31	4.0

	Dimension	r	Favor- ableness	Standard Error
31.				
a. Integration of the displayed information is difficult because dissimilar items are not different enough in appearance, and/or similar items are not sufficiently similar in appearance.	CI	.30	18	3.5
b. The amount of material presented is not excessive, and the format of the display helps even further by ordering the material.	CD	.30	83	3.3
c. The relationship between the display and the operational use of the information does not seem clear.	CR	.47	19	2.7
d. Decision-making is facilitated by the way this information is displayed.	CA	.22	85	1.6
32.				
a. One has the feeling of seeing a large number of unrelated elements.	CD	.50	21	5.2
b. There does not seem to be much of a correspondence between the general organization of the display and the operational meaning of the material.	SS	.52	21	3.0
c. In integrating the displayed information, there is very little conversion or translation required of the user.	CI	.68	79	2.9
d. The organization of the display makes subordinate, coordinate, supraordinate relationships quite obvious.	CR	.09	80	3.6
33.				
a. The making of decisions requires considerable reprocessing or recasting of the displayed information.	CA	.35	21	3.4
b. Differences between different types of material are immediately apparent.	CD	.20	80	3.6
c. Considering the uses which will be made of this display, its format seems particularly appropriate.	PC	.77	82	4.0
d. For any of a number of reasons, integrating various aspects of this display is difficult.	CI	.26	21	3.9

	Dimension	r	Favor- ableness	Standard Error
34.				
a. Relating the various displayed items to one another is difficult.	CR	.52	23	3.4
b. The important material seems to stand out quite readily.	CD	.61	79	3.0
c. The way to integrate the various information items is quite apparent from the manner in which they are presented.	CI	.09	77	3.0
d. This presentation method could result in the masking of important material.	PC	.11	15	3.8
35.				
a. Minimum demands seem to be made of user memory.	CA	.72	74	3.2
b. Materials which seem to belong together logically, don't seem to be presented the way one would expect.	CR	.69	26	3.6
c. Although signals can be differentiated from noise quite easily, certain kinds of signals are hard to differentiate from one another.	CD	.19	29	3.3
d. The general form of information representation is quite operationally relevant.	PC	.09	73	4.2

Instructions for Application

Application of the APS to evaluation of a display requires no special instructions beyond those presented in the booklet itself. The booklet describes the instrument, presents detailed instructions, and provides two sample items.

Individual evaluators vary in the time required to complete the APS. In preliminary work with the instrument, an hour or so seemed to be about an average completion duration. The obvious contributors to how long the application will take are the individual evaluator's working pace, the nature of the display being considered, the familiarity of the evaluator with the display being evaluated, and the familiarity of the evaluator with the APS itself. Few applications will take less than 45 minutes; some may take as long as two hours. Durations considerably in excess of two hours will probably be quite rare.

Instructions for Scoring

APS scoring is most easily accomplished through use of the stencils provided. There is a separate stencil sheet for each of the 12 pages of the Analytic Profile System booklet, and the page number is indicated at the top of the stencil.

The stencil is constructed of transparent material such that when it is placed on top of a completed booklet page, the checkmarks on the page will be visible through the stencil. By so placing the stencil and using the alignment guides provided, each of the seven dimensions (SN through CA) may be scored. The procedure is as follows:

1. With the booklet open to the page containing items 1-3, place the stencil for that page (marked "Page 1, Items 1-3") on top of it.
2. Align the vertical marks in the center of the SN column of the stencil directly over the vertical line on the booklet page.
3. Align the double horizontal line of the stencil with the double horizontal line of the booklet page. If this is done properly, the single horizontal lines of the stencil will coincide exactly with the single horizontal lines at the booklet's answer spaces for items 1d and 2d.
4. If these items (1d, 2d) have been checked, the checkmark will be visible through the stencil, at either the plus (+) side or minus (-) side of the appropriate horizontal line. Record the total number of such checks in the "Page Summary" of the APS booklet, under SN.
5. Slide the stencil to the left so as to align the vertical marks of the PC column over the vertical line on the booklet page. Examine again to assure that the double horizontal line of the stencil coincides with the double horizontal line of the booklet page.
6. Single horizontal lines in the PC column of the stencil will now coincide exactly with single horizontal lines at the booklet's answer spaces for items 2b and 3a. If these items have been checked, the checkmark will be visible through the stencil, at either the plus (+) side or minus (-) side of the appropriate horizontal line. Record

the total number of these checks under PC in the "Page Summary," then slide the stencil to the left and repeat the procedure for each of the remaining columns (CD through CA). Although no items on page 1 are scored for the CA dimension, this dimension is scored on the subsequent pages.

7. Turn the page of the booklet, use the stencil for that page (marked "Page 2, Items 4-6") in the same way as described above, and record results under the appropriate dimensions in the Page Summary. Continue in the same manner through the last page of the booklet.
8. At the base of the last page of the booklet, there are two summary sections in addition to the Page Summary. The upper of these two, titled "Summary of All Pages," is for use in determining a display's profile relative to the seven dimensions. Refer back to each of the 12 Page Summaries, obtain a grand total of all plus (+) marks under SN, and enter this at the plus (+) mark under SN in the Summary of all Pages. Do the same for the minus (-) marks and enter that grand total at the minus (-) under SN in the Summary of All Pages. Algebraically sum these two values, and the resultant is the SN score for the display.
9. Repeat step 8 for each of the remaining dimensions, accumulating summary values from each page and algebraically adding the plus (+) and minus (-) values, so as to derive the display's score on each of those dimensions.
10. If a total score, reflecting over-all favorableness of the display, is desired, the last summary section is used. To use this section, titled "Over-all Appraisal of Display," merely add the seven dimensional scores calculated in steps 8 and 9, enter their sum on the line provided, and perform the addition shown. The result will be a value ranging from zero (for least favorable) to a maximum of 140.

Score Interpretation

Two types of scores are provided by the Analytic Profile System. One is a descriptive profile of the display being evaluated; the other is a quantitative reflection of the evaluator's over-all opinion of the display.

Profile

The score a display attains on each of the seven dimensions is a value ranging from -20 (poorest) through zero (intermediate) to +20 (best). The relative magnitudes of the seven scores a display attains indicate best and worst aspects of the display. These scores can be helpful in pointing directions for display redesign, and in highlighting differences between alternative displays.

The scores are an analytical description of the extent to which any display meets the requirements of each of the seven dimensions, and interpretation may be facilitated by preparation of a simple profile chart of the kind shown in Figure 1. The profile chart permits determining at a glance both the areas of relative strength and weakness for a given display, and the relative superiority of one display over another on a given characteristic. Thus, display 1 of Figure 1 may be seen to be less strong on the Critical Relationships dimension than it is on any of the other dimensions. This might indicate a need to redesign in a direction making relationships easier to perceive; perhaps a qualitative rather than a digital presentation, an orientation away from "nuts and bolts" and toward "big picture."

Another way of using the profile is to compare two displays on the same dimensions, as is also shown in Figure 1. Note that the two displays score similarly on the PC, CD, SS, CI, and CA dimensions, but score quite differently on SN and CR. For the former scale, display 1 is superior, suggesting that it is presenting a more appropriate volume of stimuli. Comparatively speaking, display 2's designer might consider presenting less material, or developing means of integrating that which is presented. Alternatively, display 2 is superior on Critical Relationships, one of its two major areas of strength.

Review of the definitions of the seven dimensions, presented earlier in this manual, will suggest to the human factors practitioner the redesign avenues for any display. Specifically, higher SN scores can usually be attained by presenting less material to the display viewer, i. e., lowering the fact density. This may mean the presentation of fewer discrete information sources. It may mean integrating the information in a more summary type of presentation; it may also mean "cleaning" up the "noise" on the presentation. Any or all of these remediations will be indicated when SN scores are low.

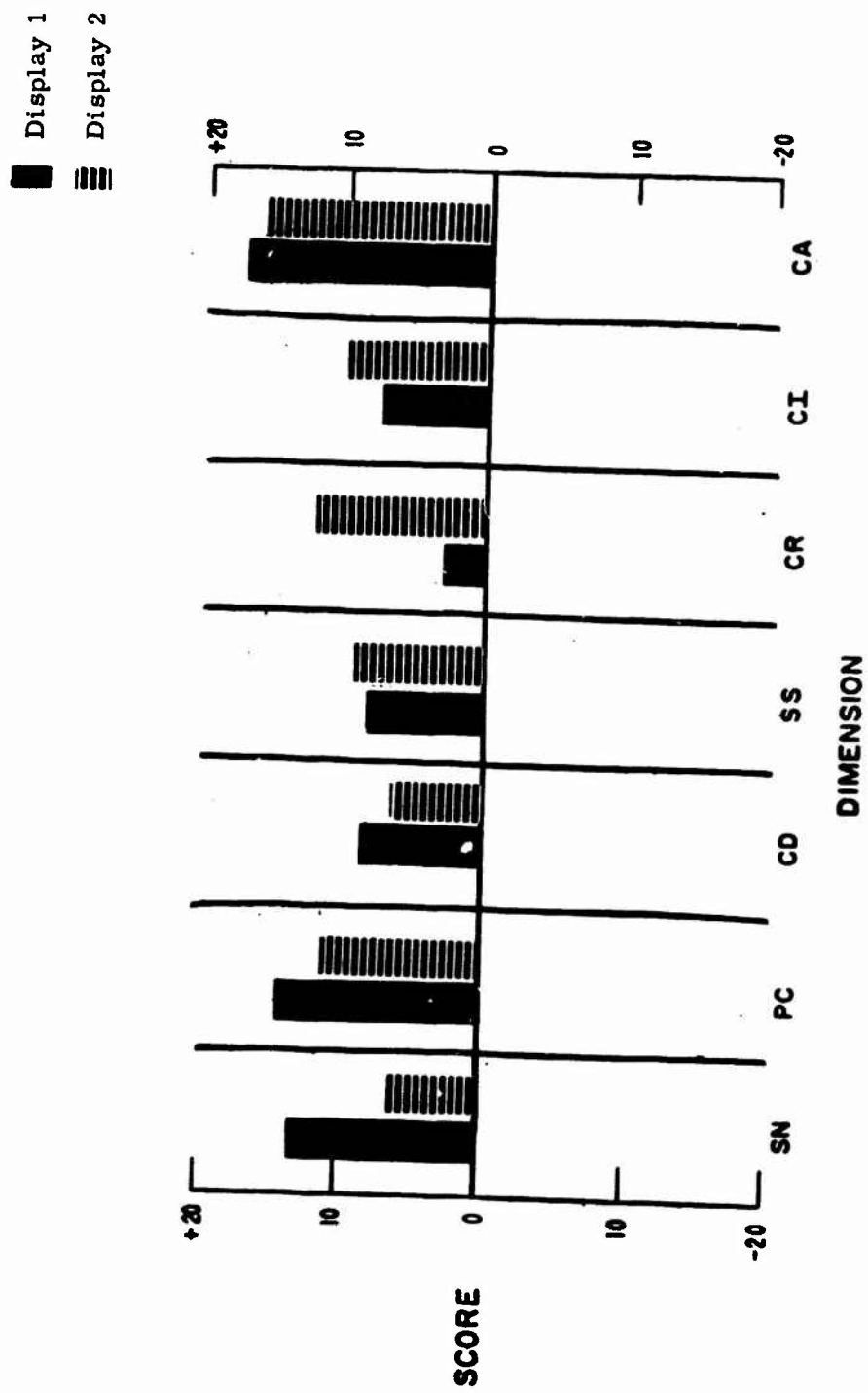


Figure 1. Profiles of two displays on the seven dimensions.

Low PC scores indicate that the over-all format of the display needs recasting. Specifically, the display may fail to yield the required perspective or to key appropriately to situational requirements. If a presentation of tables of information is involved, perhaps a situational presentation should be considered. If quantitative information is presented, perhaps trends are needed. In any case, a low PC score means an inappropriate display format, and major redesign is probably indicated.

Low CD scores indicate poor signal coding, such that signals are not readily differentiable. Information location and extraction is not facilitated by such a display. Relevant and irrelevant information are confusable. It is also possible that such displays may be of poor fidelity, in the sense of much electrically induced noise being present. The goal in increasing CD scores is to make signals more differentiable, to increase signal/noise ratios, and to lower the perceptual load on the user.

The remediation of low SS scores probably requires experimental work with a different organization of display elements in order to allow the user to reconcile various information units. A low structure scanning score indicates observer difficulty in organizing displayed signals into a meaningful structure. The display scoring low on this scale does not permit easy conceptual organization by the observer, and an alternative organizational schema should be experimented with in attempts at facilitating this organizational process.

The CR dimension pertains to the ease of perceiving relationships in the display. Low scores indicate compatibility problems, problems with the way displayed items interact, and correction requires improving this aspect of the display. Common corrections might involve graphic rather than alphanumeric presentation, qualitative rather than quantitative presentation, use of situational displays, and presenting related materials on similar scales. The principal goal is to increase the conspicuity of relationships that exist in the situation being displayed.

Low CI scores indicate observer difficulty integrating the displayed material. Here, consideration should be given to performing some of the required integrations for the observer, and displaying only the outcome, rather than displaying the elements and requiring observer integration.

Low CA scores indicate difficulty in decision making when the source of information for the decision making is the subject display. When these scores are low, the display should be examined from the point of view of lightening the mental load imposed on the user, of making preferred action alternatives more obvious, or computer aiding. For example, the display might be redesigned to indicate the required course of action rather than indicating the present situation and allowing the operator to derive the required course of action for himself.

Over-all Appraisal

In addition to the profile description of how a display stands on seven characteristics, the total score is believed to reflect the extent to which the evaluation indicates the display to be a good one or a poor one. This score ranges from zero (poorest) to a maximum value of 140. Designers may obtain gross "how-goes-it" information from this total score, then obtain the analytic support from the profile data. Thus, the total score may indicate a poor display, and the profile suggests what needs to be done to improve it.

The interpretation of APS profiles demands human factors skills and experience. Moreover, any given profile must be interpreted against the context of a given display and its proposed operational employment. Research is needed into the interpretation of APS profiles, but it is anticipated that profile interpretation will remain at the "clinical" level in the foreseeable future.

GLOSSARY

Ancillary	Subordinate, secondary, auxiliary.
"Busy"	A "busy" display is one which appears disorderly, and appears to contain an excessive number of stimuli.
"Clean"	A "clean" display is the opposite of a "busy" display and a cluttered display. It appears orderly, and does not appear to contain an excessive number of stimuli.
Cluttered	Confused, frequently also associated with "busy" displays.
Coding	Representing information in some symbolic form, the particular form being the coding method
Content Cues	Tipoff, sum and substance, gist, indication of meaning by symbol employed.
Cue	Approximately synonymous with sensory input, but a little more restrictive to meaningful elements. Sensory inputs are any noticeable elements whether meaningful or not. Cues are any meaningful noticeable elements.
Decision	Determination of a state or a course of action.
Differentiation	The act of perceiving differences in the appearance or meaning of displayed elements.
Display	Any presentation of information other than the spoken word. Usually associated with instrumented presentation. It may refer either to an individual instrument/gauge or to an assembly of presentations.
Format	The general configuration or arrangement of a display. Radar information is frequently presented in PPI format. One may speak of printed material being in prose format, plotting boards being in pictorial format, and so forth.
Induce	Draw conclusions or infer general rules or principles from a set of specific details. In the sense of obtaining a single general meaning from numerous separate details, it is similar integration. The opposite of induce is deduce, which is to reason from a general principle to specific details, facts, or circumstances.
Information Processing	The use of information in decision making.

Input	Information which is given to an operator for processing
Integration	The act of bring together separate parts or separate pieces of information into an understandable whole.
Noise	Element in display which does not convey meaningful or immediately relevant information. Contrast with signal, which is a display element conveying information.
Operations	Situations in which display will be used and interpreted.
Perspective	Background, relationship.
Scan	To look over a wide area quickly but thoroughly, as from one end to another.
Sensory Input	Any noticeable element in a display. It may be a word, a letter, a symbol, a number, a tally mark, a picture, a blip, a line, etc. See stimulus.
Signal	Element in a display conveying information, in contrast to noise, which is a display element conveying no information.
Stimulus, Stimuli	Synonymous with sensory input; any noticeable element of a display.
Trend-type Information	Information intended to indicate general tendencies and not precise values.

REFERENCES

- Fischl, M. A., & Siegel, A. I. Validation of the analytic profile system, a forced-choice instrument for visual display evaluation. Wayne, Pa.: Applied Psychological Services, 1970.
- Jorgensen, C. E. Table for determining phi coefficients. Psychometrika, 1947, 12, 17-29.
- Osgood, C. E., & Suci, G. J. A measure of relations determined by both mean difference and profile information. Psychological Bulletin, 1952, 49, 251-262.
- Siegel, A. I., & Fischl, M. A. Dimensions of visual information displays. Wayne, Pa.: Applied Psychological Services, 1967.
- Siegel, A. I., & Fischl, M. A. Dimensions of visual information displays. Journal of Applied Psychology (in press).
- Siegel, A. I., Fischl, M. A., & Macpherson, D. H. A forced-choice instrument for evaluating visual information displays. Wayne, Pa.: Applied Psychological Services, 1969.